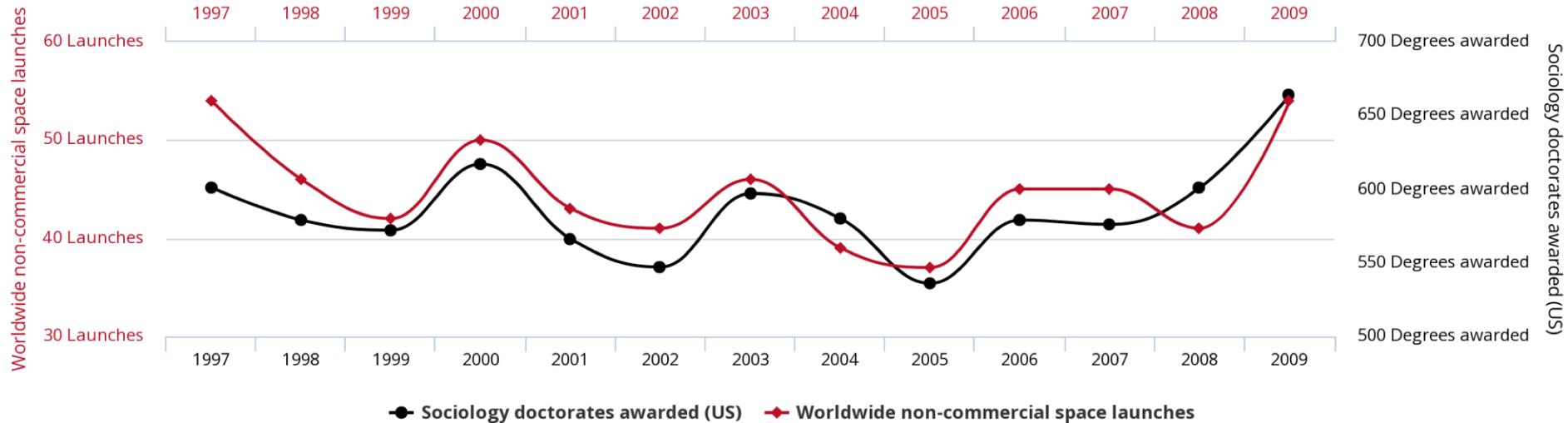


# Data Analysis Session

## Worldwide non-commercial space launches

correlates with

## Sociology doctorates awarded (US)

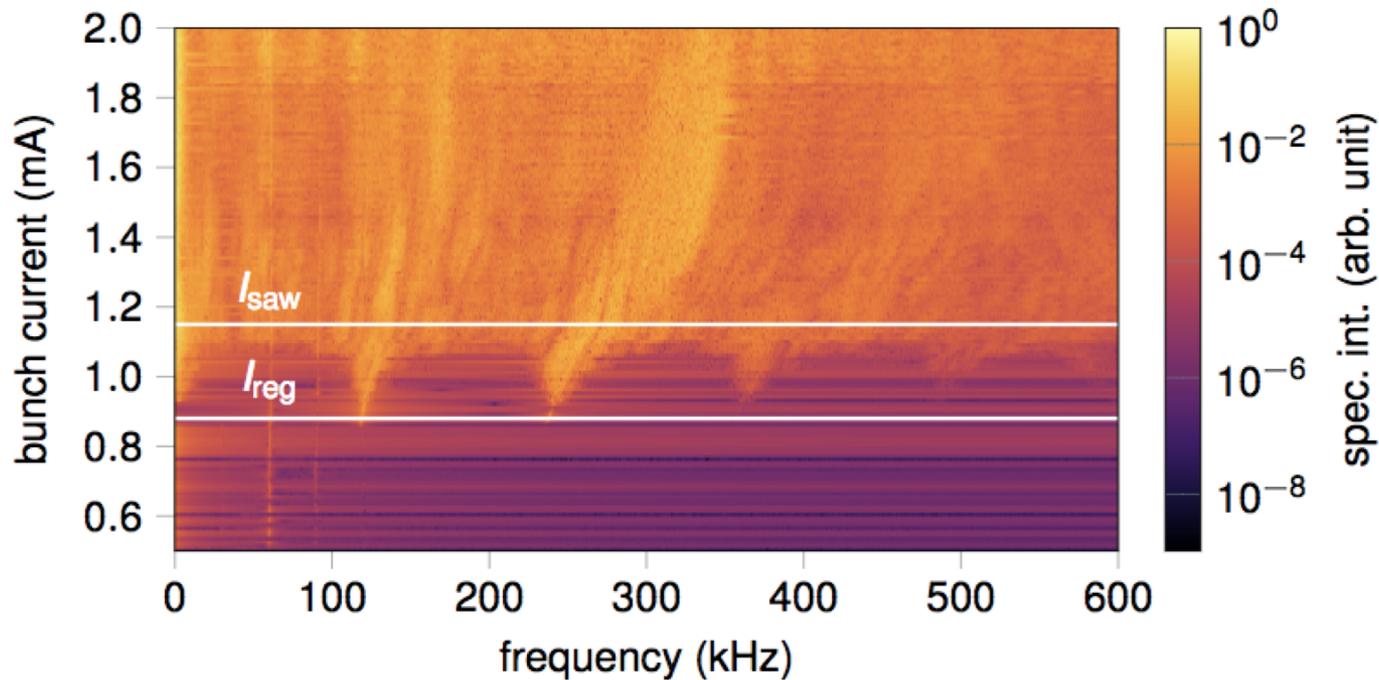


(Thanks, Jochem, for reminding me of this amazing resource.)

# T. Boltz

## Analysis of Micro-Structure Dynamics

Different Bursting Regimes: Exemplary Bunch Currents

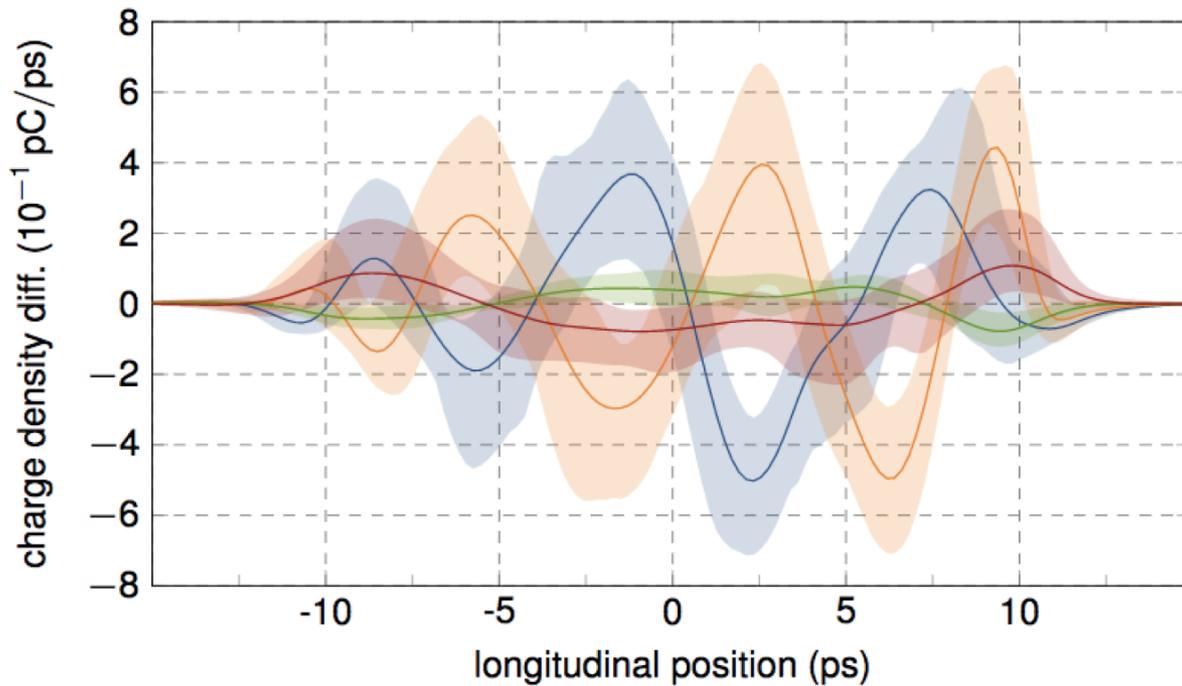


# T. Boltz

## Sawtooth Bursting Regime



Referenced Cluster Centers,  $I_{\text{saw}} = 1.15 \text{ mA}$ ,  $k = 4$

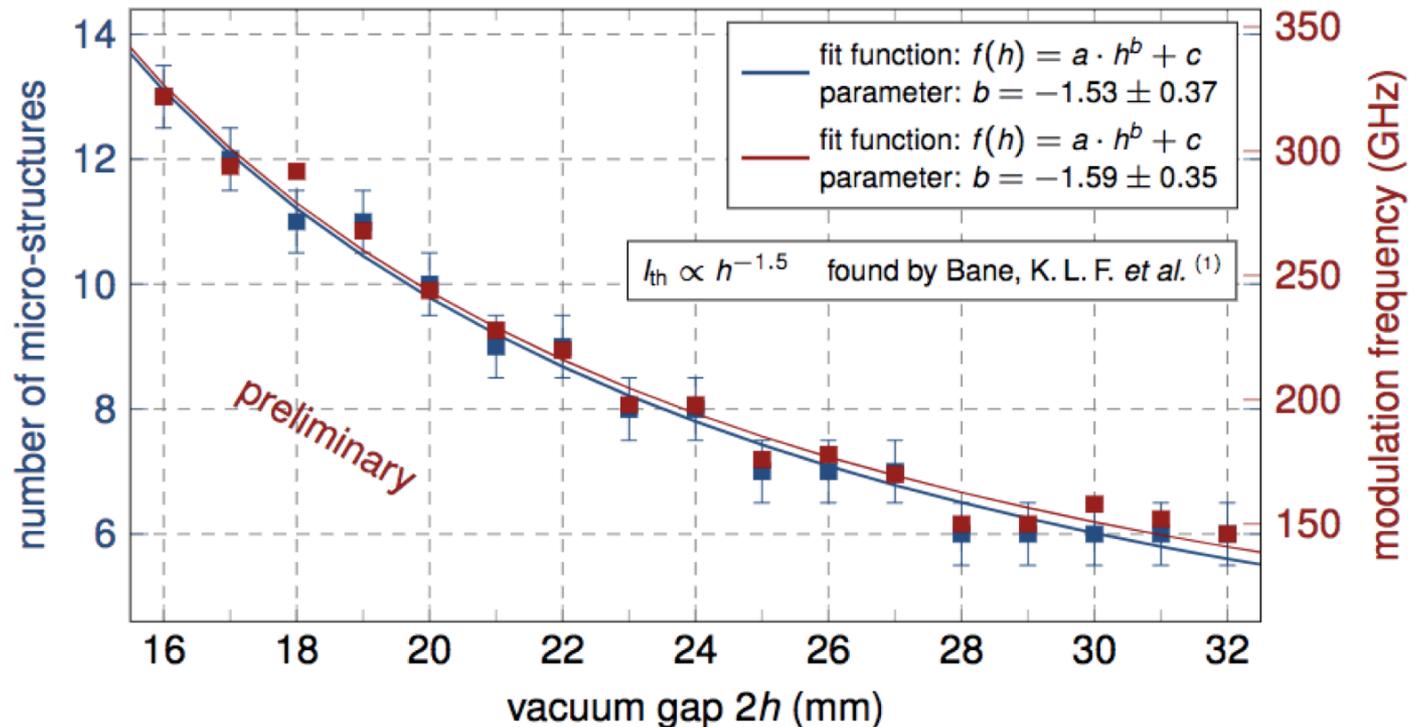


k-means clustering for bunch micro-structure

# T. Boltz

## Outlook

Further Studies using the Application of  $k$ -means



<sup>(1)</sup> Bane, K. L. F., Y. Cai, and G. Stupakov *Phys. Rev. ST Accel. Beams* **13** (2010)

Discovery potential from careful analysis of data pulled from ML?

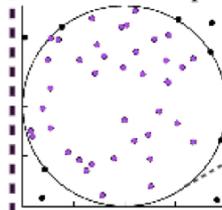
# T. Mohayai

## KDE Density and Volume – MICE Baseline

### Density:

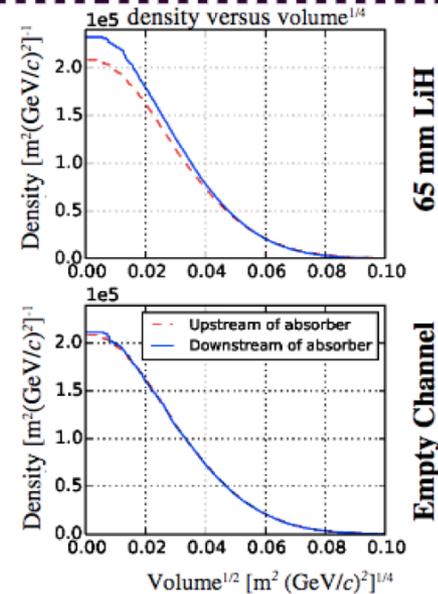
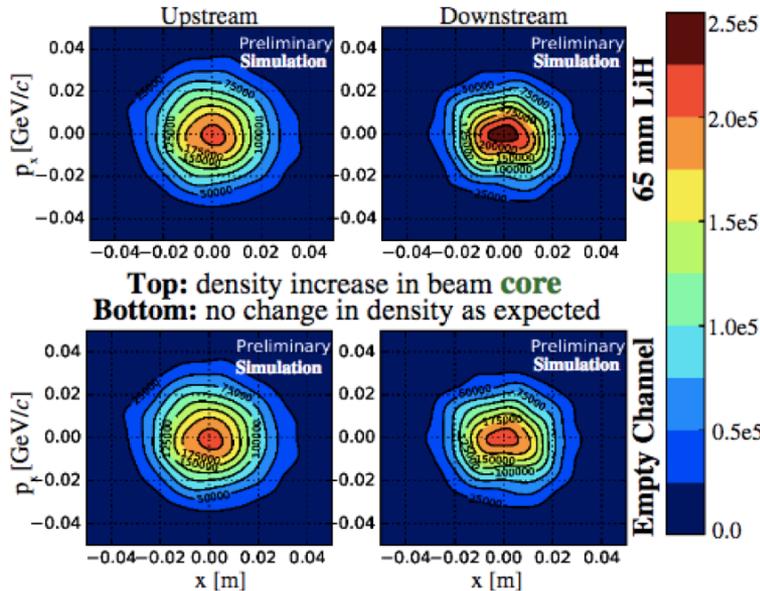
- ★ Predict density using kernels centered at each muon in 4D phase space
- ★ Extract (cluster/classify) the **core** contour (9<sup>th</sup> percentile)

2D volume example



### Volume:

- ★ Generate MC (Monte Carlo) points inside the **box** bounding the **core**
- ★ Compute **core** volume as a fraction of MC points inside the **box**

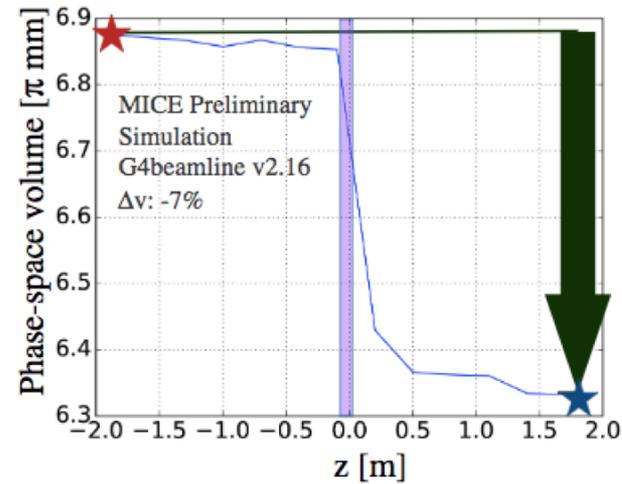
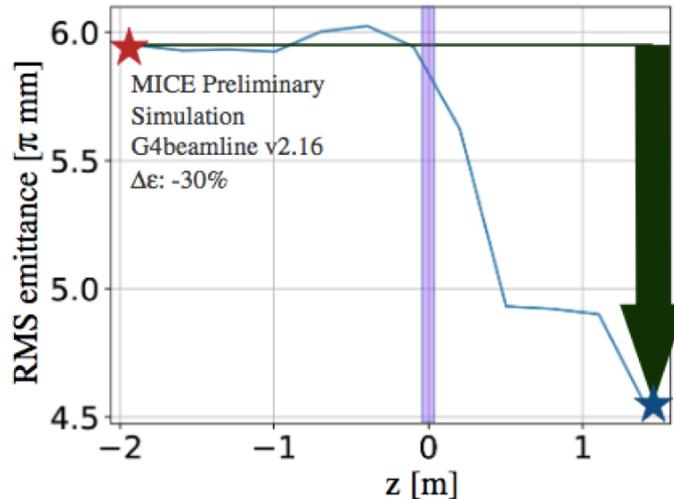
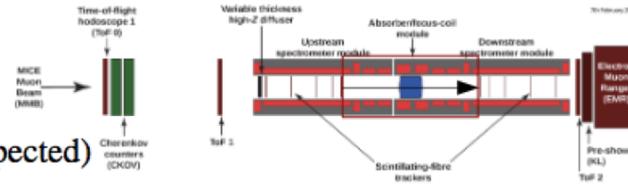


Goal: improved measurement of emittance/volume reduction.

# T. Mohayai

## Emittance vs. KDE Volume

- Beam setting:
  - ★ Input transverse emittance:  $6 \pi \text{ mm}$
  - ★ Momentum:  $140 \text{ MeV}/c$
- RMS emittance affected by transmission loss:
  - ★ Apparent emittance reduction (**-30%**  $\Delta\epsilon$  not expected)
- KDE volume in units of emittance:
  - ★ Unaffected by transmission loss (yields expected **-7%**  $\Delta v$ )
- Future extension to **supervised** learning: expected cooling performance as output data



KDE works on simulation, and we're all excited to see the data now.

# T. Mohayai

## Conclusion

- KDE based measurements:
  - ★ Provide a detailed diagnostics of the muon beam traversing a material
  - ★ Proven to be robust against beam loss
- Re-weighter routine:
  - ★ Removes correlations in the beam
  - ★ Further investigation in MC and data in progress
- Future supervised learning:
  - ★ Expected cooling performance as output data
  - ★ Supervised re-weighting techniques (e.g. boosted decision trees)
- MICE has gathered great amount of data:
  - ★ Application of KDE to data on-going

# J. Snuvernik



## Visualisation – correlation matrix

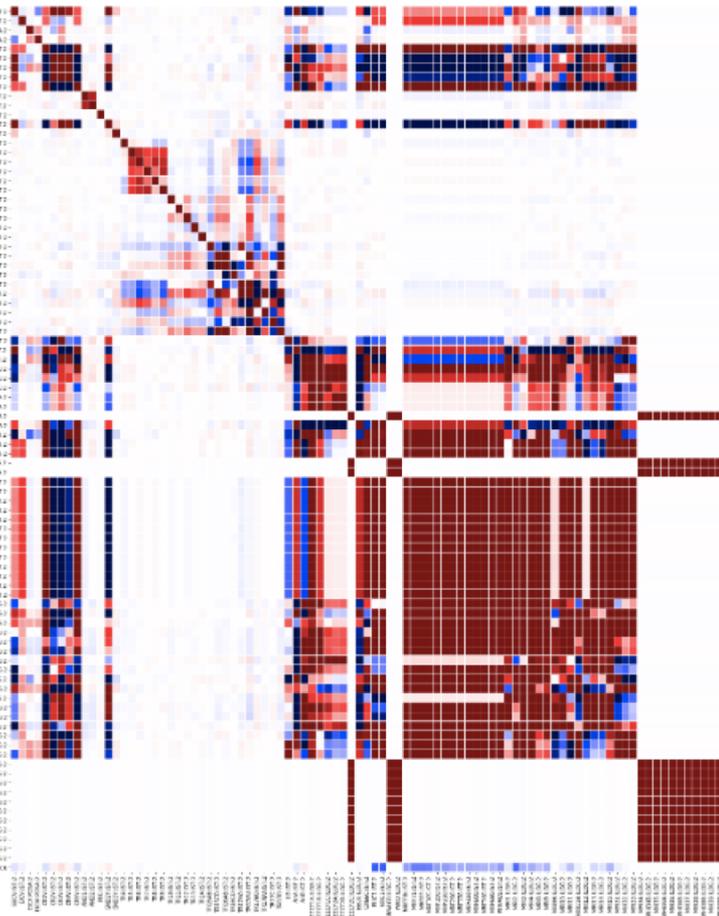
extraction and RF  
in ring cyclotron

trim coils  
in ring cyclotron

phase and loss  
monitors  
in ring cyclotron

loss monitors in  
targets beamline

Interlocks →



# J. Snuvernik

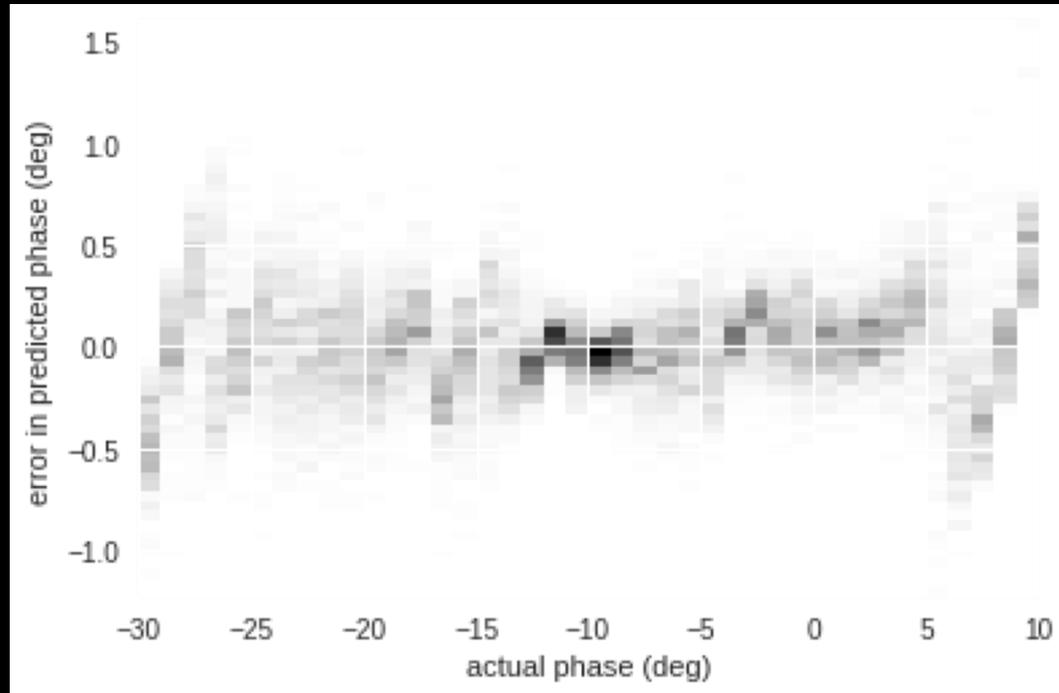
- Simple methodology for data mining
- Personal experience on HIPA data shown
  - Data preparation step most tricky
    - Discuss with controls group how this can be improved
  - Data normalisation needed for ML
- Some simple visualisation plots that can guide for large amounts of data
- Simple regression model
  - Reduce false positive rate
  - Add predictive power (RNN)

Comprehensive discussion of data preparation – very useful!

# Topics during general discussion:

- What do operators need/want? Can we give them tools based on visualization & feature reduction?
- We don't have as much data as HEP. ML is greedy for data, but do we have the necessary infrastructure & culture for "big data"?
- How to connect with other communities, e.g. theorists?
- Top-down vs bottom-up motivation for ML

# Congratulations to Jochem!



Want to say a few words on what you did for this result?